FIRE-FLOOD SEQUENCES

....on the San Dimas Experimental Forest

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FIRE-FLOOD SEQUENCES ON THE SAN DIMAS EXPERIMENTAL FOREST

by

The Staff of the San Dimas Experimental Forest

Cover: "Barrett Fire in Cucamonga Canyon"
Photograph by Ellwood Stone

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The Staff of the San Dimas Experimental Forest[1/]

Wildfires in the brush-covered mountains of southern California have repeatedly been followed by debris-laden floods downstream, but detailed information concerning both watershed conditions and flood flows before and after the fires has usually been meager. This report describes fire-flood sequences on the San Dimas Experimental Forest in the San Gabriel Mountains of southern California. Here records of rainfall and streamflow from a watershed partially burned over in December 1953 are available before and after the fire. Further, the behavior of this watershed can be compared with records of rainfall and streamflow from two comparable watersheds, one of which was partially burned in 1938 while the other has been nearly free of fire for more than half a century.

THE WATERSHEDS

The three watersheds considered here are I - Wolfskill Canyon, II - Fern Canyon, and III - Upper East Fork of San Dimas Canyon, all tributaries to the San Dimas drainage (fig. 1). The area and range in elevation of each are as follows:

Watershed	Drainage area		Range in elevation
	Sq. mi.	Acres	Feet
I Wolfskill	2.38	1,525	1,700-5,200
II Fern	2.14	1,370	2,600-5,500
III Upper East Fork	2.14	1,375	2,600-5,200

The watersheds are situated in an area of rugged relief marked by steep slopes, deep V-shaped canyons, and sharp ridges. Exposures within the watersheds are similar, for the main streams flow west to southwest. Watershed II contains an unusual feature in the form of a depression about 40 acres in area, known as Browns Flat. This depression was formed by a major land slip along the southern boundary of the watershed. Its underground drainage undoubtedly flows into watershed II, but surface runoff and erosion from about 150 acres above it accumulate in this shallow basin.

1/ Prepared under the direction of J. D. Sinclair, by E. L. Hamilton, J. S. Horton, P. B. Rowe, and L. F. Reimann. Photographs by E. Stone (Region 5, U. S. Forest Service), E. L. Hamilton, and J. S. Horton.

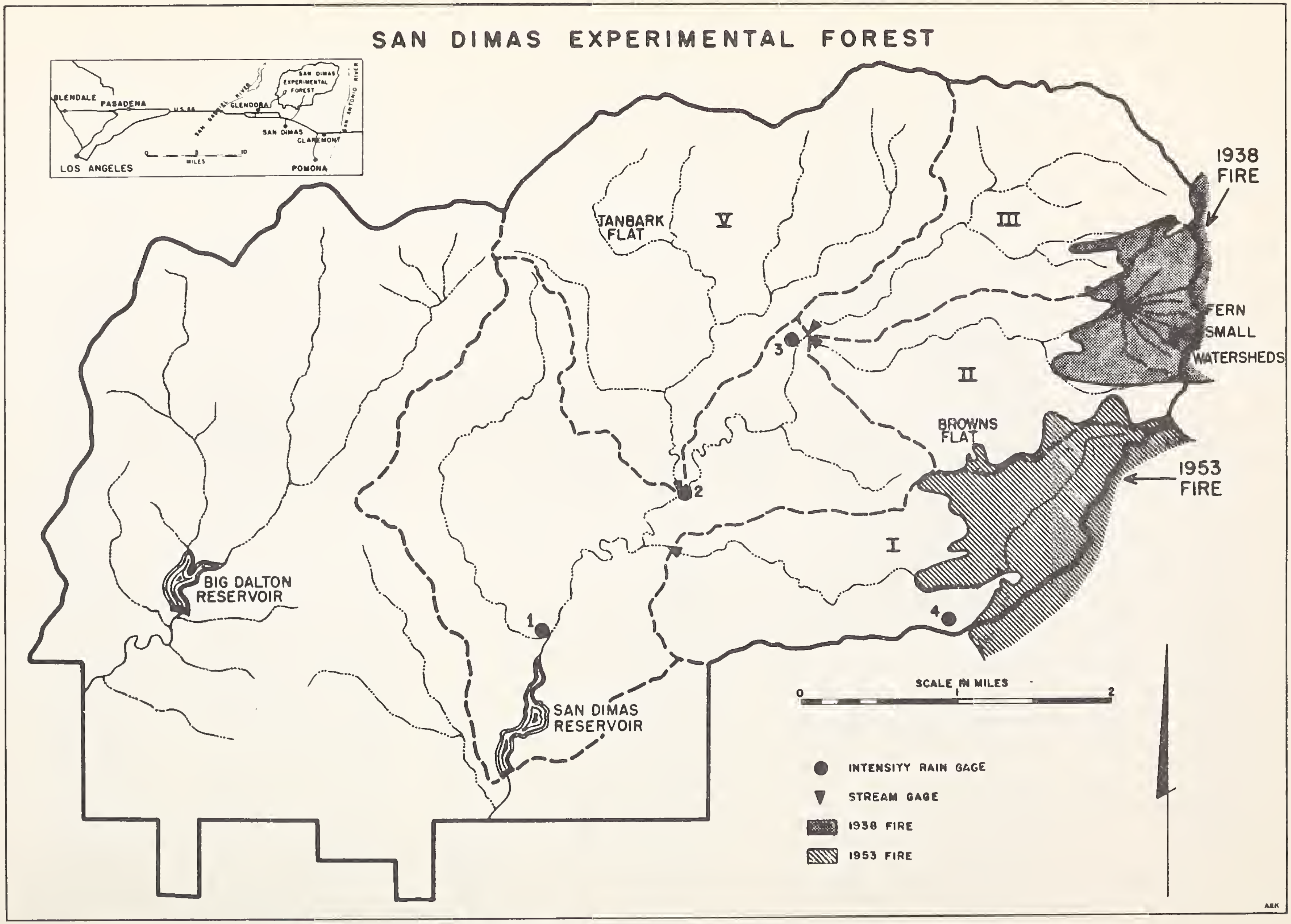


Figure 1.--The San Dimas Experimental Forest, showing locations of the 1938 and 1953 burns.

Geology and Soil

The underlying rocks of the three watersheds are primarily metamorphic, consisting of several types of gneiss and some schist. Many dikes of hard igneous material such as pegmatite, dacite, and aplite have been injected through the metamorphic rocks. A large mass of granodiorite occurs in the southwest portion of watershed I. Smaller masses of quartz-diorite occur in watersheds II and III. In general, both the metamorphic and granitic rocks are deeply fractured and weathered.

The soils derived from both the metamorphic and granitic rocks are rocky and gravelly sands and sandy loams, and are generally shallow and very unstable. Distinct soil horizons have not developed on the steep slopes that predominate in these watersheds.

Vegetation

The vegetation on the watersheds (table 1, figs. 5 and 6) is typical of the brush, or chaparral, and forest cover within comparable altitudinal ranges on the southern slopes of the San Gabriel Mountains.

Table 1.--Vegetation types in watersheds I, II, and III prior to the 1953 fire

Watershed number	Semi-barren	Chamise chaparral	Chaparral	Woodland	Big-cone spruce forest	Pine-grass
	- - - - - - - -	Percent of	watershed area	- - - - - - - -		
I	11	24	29	22	14	0
II	6	13	21	44	13	1/ 3
III	6	26	27	27	14	0

1/ All in Browns Flat

Semibarren areas are located on steep canyon walls, mostly in the lower portions of the watersheds. The vegetation is usually composed of subshrubs such as wild buckwheat (_Eriogonum fasciculatum_) and sages (_Salvia_ spp.), often with scattered live oak trees (_Quercus agrifolia_ and _Quercus chrysolepis_).

Chamise chaparral is dominated by chamise (*Adenostoma fasciculatum*). In most of this type, especially at higher elevations, bigberry manzanita (*Arctostaphylos glauca*) is abundant. At elevations below 3,500 feet hoaryleaf ceanothus (*Ceanothus crassifolius*) is often abundant.

Chaparral is usually a very dense stand of scrub oak (*Quercus dumosa* and *Quercus wislizenii* var. *frutescens*). In some of the area manzanita (*Arctostaphylos glauca* and *A. glandulosa*) and chaparral whitethorn (*Ceanothus leucodermis*) are very abundant and oak may be almost lacking.

The woodland is dominated by canyon live oak (*Quercus chrysolepis*). This type occurs mainly on north-facing slopes and consists of small closely-spaced trees 15 to 30 feet in height. Along the streams moisture-loving trees such as white alder (*Alnus rhombifolia*) and bigleaf maple (*Acer macrophyllum*) are common.

Stands of bigcone spruce (*Pseudotsuga macrocarpa*) occur on many north-facing slopes. Canyon live oak is usually found with the spruce.

An open forest of pine (*Pinus ponderosa*) grows in the Browns Flat depression in watershed II. This forest is characterized by clumps of trees surrounded by grassland.

FIRE HISTORY

There are no firm records of fires within any of the three watersheds before 1919. However, oldtimers claim that a fire burned into watershed I and the Browns Flat area of watershed II in 1884. In November 1938 (table 2, fig. 1) a fire entered the San Dimas Experimental Forest and burned 359 acres in watershed II, and 45 acres in watershed III.

Wildfires burned over more than 170,000 acres of brush- and forest-covered lands in southern California during 1953, the greatest loss of watershed cover since 1919. Low fuel moisture helped start the fires, and their spread was aggravated by hot, dry, windy conditions.

North winds and low humidities characterized the summer and fall. Rainfall during the calendar year 1953 was the lowest of record for southern California, and totaled only 8.45 inches at Tanbark Flat on the San Dimas Experimental Forest. The fire season normally is ended by rains in October and November, but this year only 1.44 inches of rain fell at Tanbark Flat from October 1 to December 1, compared to an average of 3.32 inches during this period. The average rainfall from October 1 to January 1 is 8.82 inches, but in 1953 this 3-month period produced only 1.85 inches.

Table 2.--Area of known burns in watersheds I, II, and III by type of vegetation and intensity of burn

Watershed and intensity of burn	Semi-barren	Chamise chaparral	Chaparral	Woodland	Bigcone spruce forest	Pine-grass	Total
	Acres						
I--Wolfskill							
1953 burn							
Severe 1/	21	125	105	27	0	0	278
Partial 2/	29	6	23	63	84	0	205
Total 1953	50	131	128	90	84	0	483
II--Fern							
1938 burn							
Severe	12	51	104	113	2	0	282
Partial	1	0	2	70	4	0	77
Total 1938	13	51	106	183	6	0	359
1953 burn							
Severe	0	0	10	0	0	0	10
Partial	0	0	3	28	5	0	36
Total 1953	0	0	13	28	5	0	46
III--Upper East Fork							
1919 burn	2	11	14	1	0	0	28
1938 burn							
Severe	1	13	14	4	4	0	36
Partial	0	0	2	1	6	0	9
Total 1938	1	13	16	5	10	0	45

1/ Severe - crowns completely consumed.

2/ Partial - in woodland, bigcone spruce forest, and some of the oak chaparral, the litter usually severely burned but crowns unburned. In semibarren and some of the chaparral types, "partial burn" indicates spotty burning, with patches of complete burn mixed with unburned cover.

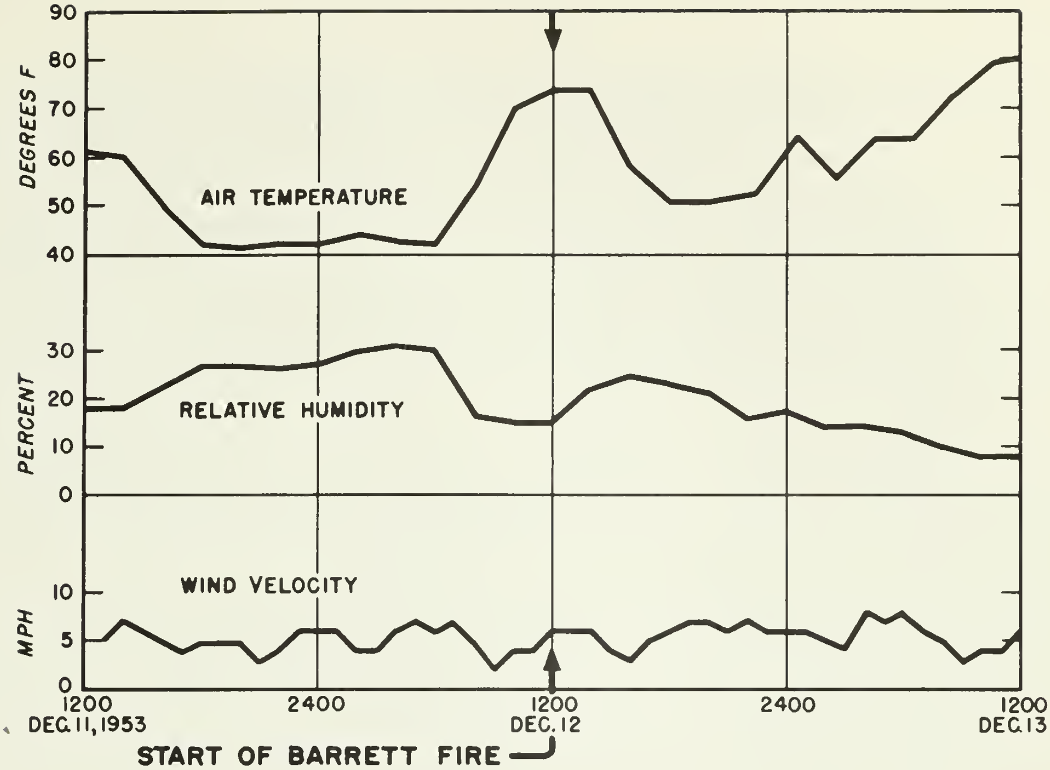
The Barrett Fire

On December 12, 1953, a fire started in Barrett Canyon, a tributary of San Antonio Canyon on the Mt. Baldy District of the Angeles National Forest, through the carelessness of a smoker. Santa Ana weather conditions, dry northerly wind of the foehn type, prevailed at the time. Since October 1 there had been only five rainy days, the effects of which had been counteracted by 29 days having an average relative humidity of 25 percent or less. At Tanbark Flat, about 6 miles northwest of Barrett Canyon, air temperatures were 1.0, 1.8, and 1.6 degrees above average for the months of October, November, and December, respectively. Climatic data from Tanbark Flat for a day before and after the start of the fire (fig. 2, upper portion), show that conditions for fire spread were good. Air temperature was high and relative humidity low, and the wind had been persistent throughout the day and night preceding the fire's start. The wind velocity was probably much lower at Tanbark Flat than at the fire. Weather conditions and difficult terrain hindered fire fighting, and the fire was not considered under control until December 19. During this time it spread eastward into the San Bernardino National Forest and burned a total of 3,600 acres of chaparral.

The weather during the mop-up period was somewhat cooler, but because it continued dry there could be no certainty that the fire was out until rain came. On December 27 a violent windstorm occurred (fig. 2, lower portion). At Tanbark Flat the wind increased from an average hourly velocity of 3 miles per hour to 18 miles per hour in a period of 4 hours, and after a short respite, increased to 27 miles per hour. Gusts of 40 miles per hour for 1 minute duration were recorded there. Wind velocities of 80 miles per hour at Ontario Airport and 55 miles per hour at Mount Wilson were also reported at this time. These adverse weather conditions caused the fire to break out at about 1900 hours. It spread rapidly both east and west, burning an additional 4,400 acres of chaparral before it was controlled on December 31.

The Wolfskill Burn

Under the drive of the northeast wind the Barrett fire break-out jumped across the bottom of San Antonio Canyon and spread into Evey and Palmer Canyons on the west side of San Antonio Canyon. The fire rushed up Evey Canyon and crossed the divide into the San Dimas Experimental Forest at the head of Wolfskill Canyon (watershed I) during the night of December 27 or the early morning of December 28. The fire, very intense at first, consumed all vegetation in its path. Although the intensity of the fire soon decreased, it continued to spread westward down the ridges, consuming the chaparral and burning underneath the oak-woodland and bigcone spruce stands without consuming the crowns. Strong north winds kept the fire from spreading northward in watershed II. By noon of December 28 the wind had died down and much of the fireline became inactive. The hottest portion of the fireline was the center ridge in the upper part of watershed I, where the fire was burning slowly down the slope, but only in the chamise. By this time the humidity had risen and crowns of oak and manzanita did not ignite. North of the center ridge in watershed I the fire was burning downhill very slowly. On the south side of the watershed the fire was burning only in a few spots.



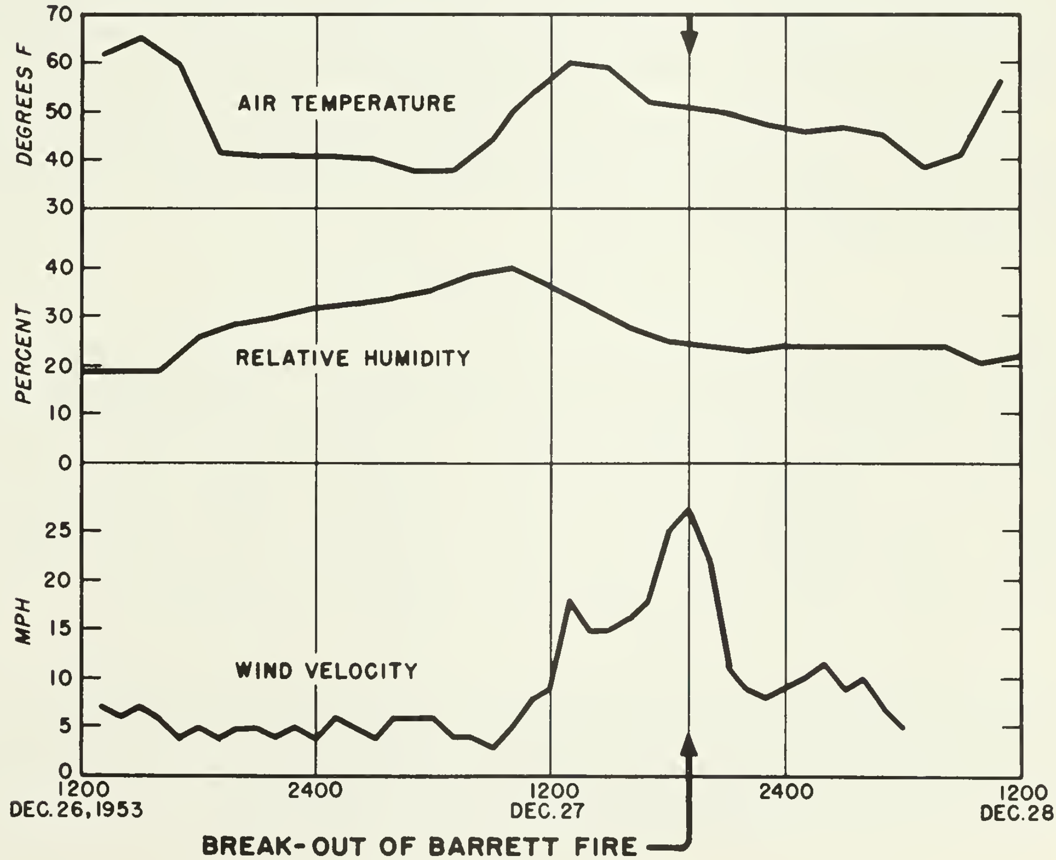


Figure 2.--Weather records at Tanbark Flat before and after start of the Barrett Fire and the Barrett Fire break-out.

By noon of December 29 the fire was not advancing to any extent, even though much of the line was uncontrolled. The chamise on the center ridge in watershed I was burned out and the fire was burning in many spots in down trees, and in debris in the main channel of the watershed. On the north side of the watershed the fireline was very irregular, and occasional flareups were occurring, many of these in unburned islands. At this time it was planned to fire out portions of watershed I from prepared lines to the west of the fire, but changed fire-weather conditions made backfiring impossible. Crews were then able to attack the fire directly and later to control it in watersheds I and II along the irregularities of the fireline.

The headwaters area of watershed I was very severely burned over (table 2, figs. 5 and 6). Crowns of all the oaks were consumed, and in a small plantation of Coulter pine there probably are no trees now alive. The fire also crowned in the oak-woodland type in fringes along the southern boundary and in the upper southeastern part of the watershed. In the latter area bigcone spruce received its greatest damage and shows the most singeing. Where the fire did not crown in oak-woodland and bigcone spruce the litter under the trees was burned severely and a large percentage of the crowns was singed. The leaves will drop from these damaged crowns; some of the oak trees will undoubtedly sprout from their branches. Practically all the chamise chaparral and most of the heavy brush within the firelines was consumed. Only a small percentage of chamise chaparral near the north end of the fireline in watershed I was partially burned. The open semibarren and woodland-sage areas were often spottily burned, with large shrubs and trees generally untouched.

In watershed II small patches of chaparral along the ridge tops were consumed, but most of the area burned was in the woodland and bigcone spruce types (table 2). The litter on the ground in these types was completely consumed but the crowns were untouched.

POST-FIRE RAINFALL

The 1953 burn in watersheds I and II was still being patrolled on January 11 when the first post-fire storm occurred. Precipitation totaled 0.95 inch in the Wolfskill intensity gage at 3,600 feet elevation and was mostly in the form of snow above 3,100 feet. The following week a second storm occurred, totaling 6.36 inches at the Wolfskill gage. The storm persisted four days (January 17 to January 20) and was of moderately high intensity. All the precipitation was in the form of rain. Three days later (January 23-25) a third storm brought 6.55 inches of precipitation. This storm was mostly rain, with some snow during the latter portion.

It was not possible to measure the catch of the rain gages in watersheds I, II, and III for the individual storms, but the total of the three storms indicated that the rain was fairly uniform over these watersheds for the whole period. Total rainfall for the three storms has been broken down by days from intensity-gage records (table 3).

Rainfall increased with elevation during the three storms, as is indicated by the following records, obtained from intensity gages located at different levels:

Raingage location	Elevation	Rainfall
	Feet	Inches
1--San Dimas Guard Station	1,700	10.79
2--Flumes 4 and 5	2,200	11.23
3--Flumes 2 and 3	2,600	11.84
4--Wolfskill	3,600	13.86
5--Fern Canyon dams	4,700	14.50
6--Fern watershed No. 2	5,200	15.09

Rainfall rates were low in all three watersheds in the storm of January 11-12, 1954 (table 4). In the storm of January 17-20, 1954, rainfall intensity was generally highest in watershed II, where the maximum hourly rate was 1.03 inches per hour. During this storm, in watersheds I and III the hourly rates were 0.64 and 0.63 inches per hour respectively, a fairly high sustained intensity. The storm of January 23-25, 1954 gave much higher short-time rainfall rates than the previous storm. In this storm watershed I had rainfall intensities considerably higher than the other two watersheds, except for the 1-hour rate, which was exceeded in watershed II.

Table 3.--Daily rainfall[1] during January 1954 on watersheds I, II, and III

Date	Watershed number I	Watershed number II	Watershed number III
	Inches		
January 11	.04	.04	.03
January 12	.85	1.26	.82
Total	.89	1.30	.85
January 17	0	.03	.03
January 18	1.64	1.89	1.55
January 19	4.19	5.33	5.56
January 20	.15	.15	.07
Total	5.98	7.40	7.21
January 23	0	0	.01
January 24	4.02	3.26	3.60
January 25	2.13	1.71	1.22
Total	6.15	4.97	4.82
Total (3 storms)[2]	13.02	13.67	12.88

1/ Daily rainfall distribution according to intensity gages.
2/ Watershed averages from records of standard rain gage network.

Table 4.--Rainfall rates in watersheds I, II, and III

Storm date	Watershed number	Duration (minutes) 5	15	30	60	360
		Inches per hour				
Jan. 11-12, 1954	I	.48	.24	.26	.23	.10
	II	.36	.32	.34	.33	.16
	III	.24	.28	.28	.26	.10
Jan. 17-20, 1954	I	1.32	1.08	.90	.64	.40
	II	1.44	1.36	1.16	1.03	.64
	III	1.68	1.00	.74	.63	.50
Jan. 23-25, 1954	I	2.52	2.40	1.54	.79	.49
	II	1.80	1.28	1.14	.83	.42
	III	.96	.64	.60	.48	.27

THE EFFECTS OF FIRE

Flood Flows in Watershed I

The rainfall quantities and rates in the second and third post-fire storms resulted in high and abnormal streamflow at the mouth of watershed I. Charles Colver, the field observer in San Dimas Canyon, gives the following account of events at No. I streamgaging station:

"I arrived at Flume 1 (fig. 9) on January 19, 1954 at 0019. It was raining steadily, the flow was 1.8 c.f.s. in the V-notch weir and starting to get muddy (rainfall totaled 1.92 inches). I returned to Flume 6 to get Campbell, and on our way back to Flume 1 we noticed that the main San Dimas Creek was running high and muddy. Arriving at Flume 1 at 0200, we found that the 3-foot tail gate had overtopped so we changed the flow from the V-notch to the 3-foot flume immediately. The flow was 29 c.f.s. in the 3-foot flume, the first definite peak, and rain totaled 2.60 inches. By 0240 the flow increased to 43 c.f.s. bulked by mud, rocks, and debris (rainfall 2.70 inches). About this time the stillwell inlets to the 3-foot flume silted up and we started observations at the 10-foot flume. It was still raining steadily but the flow in the 10-foot flume decreased to 15 c.f.s. at 0328 (rainfall 3.09 inches). The flow then started up and by 0430 it was up to 36 c.f.s. Campbell and I were sitting in the shelter house and heard a great roar and the ground began to tremble. We ran outside and saw a great wall of water, logs, and boulders just entering the flume. In a few seconds it was past but the crest reached an average of 6.5 feet depth in the 10-foot flume (rainfall 3.66 inches). This would be a bulk flow of 1,025 c.f.s. The wave passed through the flume at 0438 and passed by the San Dimas Guard Station 1-1/2 miles downstream just 15 minutes later. By 0455 the flow had dropped to 2 feet depth (213 c.f.s.) after holding at 5 feet depth (710 c.f.s.) for about 10 minutes. This crest cleaned the channel to bedrock except in backwaters where deposition occurred. The upper side of the flume was piled high with gravel and boulders (fig. 9B). One boulder about 4 feet in diameter lodged in the 3-foot flume. The Wolfskill Canyon road was completely washed out and the 6-inch water main was carried away where it crossed the canyon.

"I am satisfied that half the bulk in the large crest was debris. There were large logs bobbing up and down, and the grating of the rocks on the flume floor and walls made a great deal of noise.

"The crest that we experienced at 0438 was completely unexpected, and was rather unnerving. I felt that the channel had blocked, and then broken, causing the sudden surge. If this crest had been 1 foot higher, I believe that the flume and the entire area would not have survived. We honestly did not know whether to run for high ground or stay and try to get records. I observed that the small side canyons in the area did not run off during the storm at all, and the larger ones which did run were absolutely clear. Nothing unusual took place during the remainder of the forenoon; however, it continued to rain.

"The flow dropped to 7 c.f.s. by 1200 showing a very sudden drop from the high peak of early morning. It was still very muddy, but had not enough volume to carry much debris. The smell of fire was very strong, and a great deal of partially burned wood was deposited along the sides of the stream channel. Just after noon it rained hard and the flow started up, carrying more debris. A peak reached at 1642 (total rain so far 5.95 inches) went to 174 c.f.s., again as a surge loaded with logs, rocks, etc. Again it fell off very rapidly and by 1908 was down to 15 c.f.s. Rain slackened at about 2030, resumed about midnight, and finally stopped at 0230 on January 20 with a total of 6.36 inches for the storm."

After the storm was over, the silt traps were cleaned out and the boulder was removed from the 3-foot flume with the aid of dynamite. This work had just been finished when the storm of January 23-25 moved in. By 3 p.m. on January 24, 1.77 inches of rain had fallen and Charles Colver was again at the streamgaging station. He says: "At about 1500 the flow was 8 c.f.s. in the 3-foot flume and very muddy. It rained steadily and at 2245, after 4.02 inches had fallen, a large crest passed through the gaging station, overtopping the 3-foot flume. Due to upstream deposits the flow in the 10-foot flume was very irregular and I had to take readings at the staff gages on both sides. This crest was about 145 c.f.s. It dropped gradually to 85 c.f.s. at 2309, to 28 c.f.s. at 2340, and 12 c.f.s. at 0033 on January 25 (total rain at this time 4.82 inches).

"At 0059 we heard a roar as on January 19 and saw a large peak go by. It reached an average depth of 5 feet (710 c.f.s.) in the 10-foot flume but appeared to contain less floating debris than the previous storm peak of 6.5 feet. The flow was about 3.8 feet deep, or 500 c.f.s., at 0106. The flow dropped to 160 c.f.s. by 0215 (5.90 inches of rain), but rose to another peak of 200 c.f.s. at 0221. The flow dropped to 34 c.f.s. by 0540, at which time the rain stopped with a total of 6.55 inches for the storm. We cleaned out the silt traps and reset the recorders by 0910. The flow at that time was 12.6 c.f.s. The damage done by the second storm was a continuation of what the first one started. Many more large boulders were moved and a great deal more channel cutting and depositing took place."

This experience is not unusual in southern California. Rainfall of the first storms during the winter rainy season, falling on summer-dried soils, seldom produces high storm flows from watersheds with undisturbed vegetation. When the vegetation has been destroyed by fire, however, peak discharges from such storms may be greatly increased and bulked with debris, resulting in serious flood damage. The large quantities of logs, rock, ash, and other debris carried by the first flows from a burned area may also cause temporary damming of stream channels, with the impounding of water and debris (fig. 8). Failure of these temporary dams and sudden release of the material caught behind them can cause debris-laden flood waves of the type observed from watershed I on January 19. In this instance the initial wave reached about 1,000 c.f.s., and was followed by a flood flow of some 700 c.f.s. for a period of about 10 minutes.

Watershed Reactions to Fire

The peak flow of a stream, defined as its greatest instantaneous flow during any period, is a good indicator during storms of the reaction of a watershed to changes in vegetation, soil,or land use. Many studies have shown that storm streamflow is more uniform from a watershed with an undisturbed soil mantle well protected by vegetation than from a watershed which has had soil or protective cover damaged.

Did the partial denudation by fire of watersheds II and III in 1938, and of watersheds I and II in 1953, affect the peak flows from these watersheds? In order to find out, peak flows from the three watersheds were compared for several storms before and after the fires. Two conditions of watershed wetness are represented in this comparison. In one condition so little rain had fallen prior to the storms that the watershed soils were still partly dry. In the other, sufficient rain had fallen previously to have wet the soils through. For each condition of watershed wetness the storms selected for before-and-after comparisons were closely similar in size and other characteristics. For these comparisons streamflow peaks were expressed in cubic feet per second per square mile of watershed area (tables 5 and 6); this was done to make the peak flows comparable despite differences in watershed area.

The 1938 fire did not affect watershed I. Therefore, the peak flows from this watershed can be used before and after the 1938 fire as a base for judging the effects of burning in the other watersheds. The 1953 fire did not burn into watershed III. This watershed can be used as a base for examination of effects of the 1953 fire provided carryover effects of the 1938 fire in this watershed are found to be negligible for some time prior to 1953. By expressing the peak flows as ratios (figs. 3 and 4) the data in tables 5 and 6 can readily be interpreted, and carryover effects of the 1938 fire can be determined.

Table 5.--Peak flows from three watersheds, under dry soil conditions[1], as affected by two fires

Date of storm	Rainfall[2]		Peak flow rates		
	During storm	Before storm[3]	Watershed I	Watershed II	Watershed III
	In.	In.	C.s.m.	C.s.m.	C.s.m.
Before 1938 fire					
Jan. 31-Feb. 2, 1936	4.40	2.20	2.05	1.42	.98
Dec. 14-16, 1936	4.07	3.42	1.04	.93	.31
Dec. 9-11, 1937	3.14	.04	1.42	.58	.72
Average	3.87	1.89	1.50	.98	.67
After 1938 fire[4]					
Dec. 17-21, 1938	7.27	2.20	6.53	55.01	11.84
Jan. 6-12, 1950	5.61	2.46	17.46	26.47	19.66
Before 1953 fire					
Nov. 9-12, 1944	8.34	1.28	35.85	32.37	31.30
Dec. 21-25, 1945	13.00	2.11	31.87	26.49	26.31
Nov. 30-Dec. 1, 1952	2.43	3.78	2.26	1.49	1.81
Average	7.92	2.39	23.33	20.12	19.81
After 1953 fire[5]					
Jan. 17-20, 1954	6.56	2.60	428.76	20.20	5.37

1/ Watershed soils partially dry; less than 4 inches of rain before storm

2/ Measured in Tanbark Flat intensity gage.

3/ From October 1 to start of storm.

4/ Fire in November burned 26.2 percent of watershed II and 3.3 percent of watershed III. Watershed I unburned.

5/ Fire in December burned 31.7 percent of watershed I and 3.4 percent of watershed II. Watershed III unburned.

Table 6.--Peak flows from three watersheds, under wet soil conditions[1], as affected by two fires

Date of storm	Rainfall[2]		Peak flow rates		
	During storm	Before storm[3]	Watershed I	Watershed II	Watershed III
	In.	In.	C.s.m.	C.s.m.	C.s.m.
Before 1938 fire					
Jan. 31-Feb. 1, 1938	1.70	8.97	1.50	1.14	1.19
Feb. 2-4, 1938	3.74	10.67	7.45	5.93	3.76
Average	2.72	9.82	4.48	3.54	2.48
After 1938 fire[4]					
Jan. 5, 1939	2.35	9.48	3.66	12.61	5.09
Jan. 31-Feb. 4, 1940	3.59	8.89	1.54	8.74	3.06
Before 1953 fire					
Jan. 31-Feb. 3, 1945	6.18	13.36	16.24	15.81	12.99
Feb. 5-6, 1950	2.56	14.73	1.31	1.11	.95
Jan. 27-30, 1951	5.92	9.70	4.72	3.60	2.77
Average	4.89	12.60	7.42	6.84	5.57
After 1953 fire[5]					
Jan. 23-25, 1954	4.76	9.26	296.99	21.33	14.29

1/ Watershed soils wet through; more than 8.5 inches of rain before storm.

2/ Measured in Tanbark Flat intensity gage.

3/ From October 1 to start of storm.

4/ Fire in November burned 26.2 percent of watershed II and 3.3 percent of watershed III. Watershed I unburned.

5/ Fire in December burned 31.7 percent of watershed I and 3.4 percent of watershed II. Watershed III unburned.

Under dry soil conditions prior to the 1938 fire the peak flows from watersheds II and III averaged .65 and .45, as great, respectively, as those from watershed I. Under wet soil conditions the corresponding flow ratios were .79 and .55. During the rainy season following the 1938 fire the peak flow ratios of the two burned watersheds rose sharply. While the watersheds were relatively dry the peak flow of watershed II was 8.4 times as great as that from watershed I; that of watershed III was 1.8 times as great. After the watersheds had become wet the corresponding values were 3.4 and 1.4.

The above comparisons do not show the actual increases in peak flows due to the fire. For example, had watershed II not been burned in 1938 the peak flow of the storm of December 17-21, 1938, according to the relations between peak flows from watersheds I and II before the fire, should have been only about .65 of that from watershed I, or 4.24 c.s.m. It follows then that the peak flow of 55.01 c.s.m. from watershed II for this storm was about 13 times the flow that would have been expected had the watershed been unburned. The peak flows during the two post-fire storms in 1938 were raised to the following levels by the fire:

	Dry soil conditions	Wet soil conditions
Watershed II, 26 percent burned	13.0 times normal	4.4 times normal
Watershed III, 3 percent burned	4.0 times normal	2.5 times normal

A year later, as shown by the storms of January, 1940, peak flows under dry soil conditions had dropped considerably, while those under wet soil conditions were higher than they had been shortly after the fire. But by 1944, 6 years after the fire, the flows under both conditions of watershed wetness had dropped back to levels only a little greater than before 1938. Thus it was possible to appraise the effects of the 1953 fire by using the peak flows after 1944.

During the 9-year period before the 1953 fire, under dry soil conditions, the peak flows from watersheds I and II averaged 1.18 and 1.02 times as great, respectively, as those from watershed III. When the soil was wet through, the corresponding ratios were 1.33 and 1.23. After the 1953 fire, however, the peak flow from watershed I was 79.8 times as great as that from watershed III when the soil was dry, and 20.8 times as great when the soil was wet. The corresponding ratios for watershed II were 3.8 and 1.5. The peak flow from watershed I during the storm of January 17-20 was heavily bulked with large rocks, logs, and other debris (fig. 8). The peak flow during the storm of January 23-25 was less bulked with debris, but the period of high flow was longer.

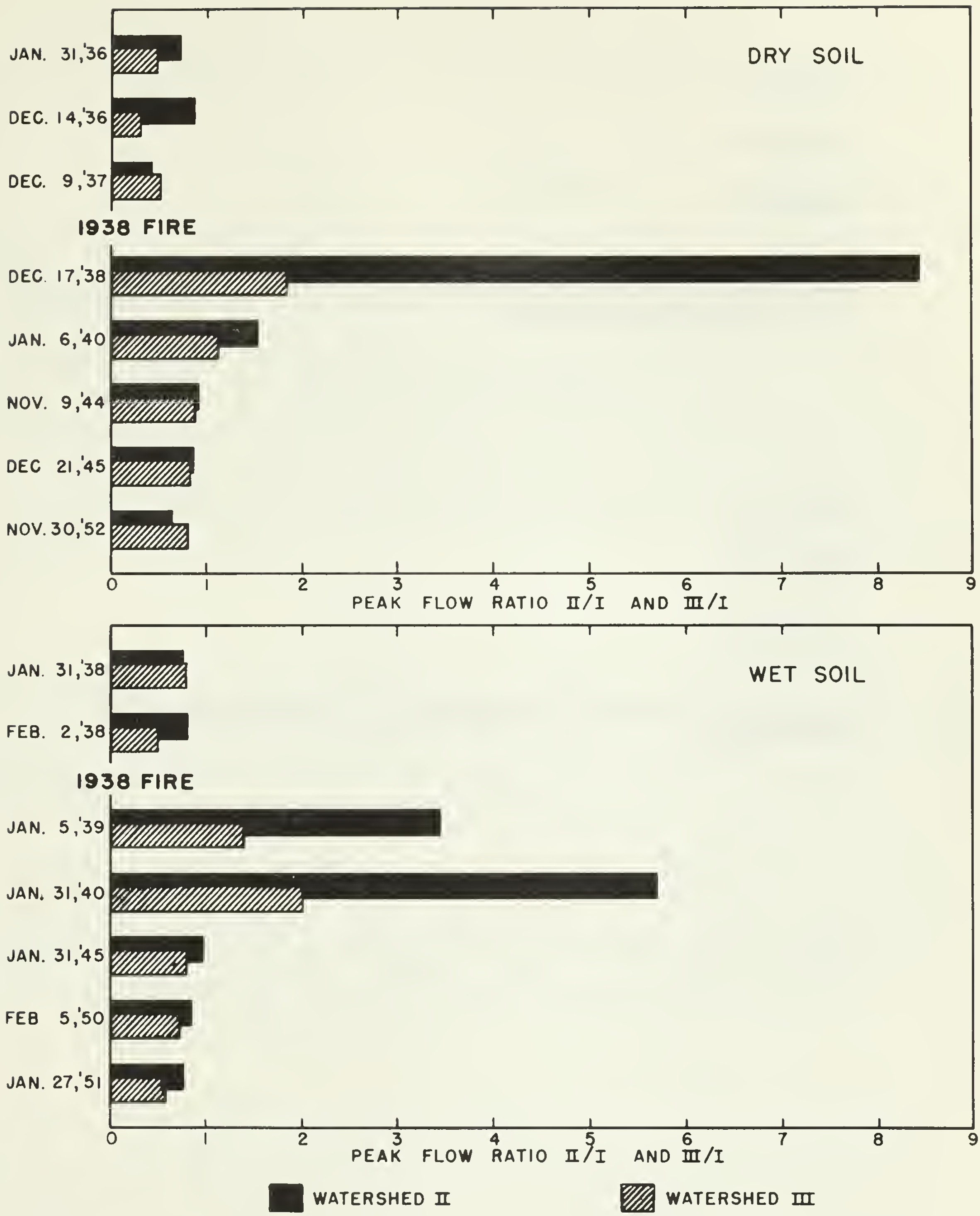


Figure 3.--Relative magnitudes of peak flows before and after the 1938 fire--peak flows per square mile from watersheds II and III relative to those from watershed I, unburned in 1938.

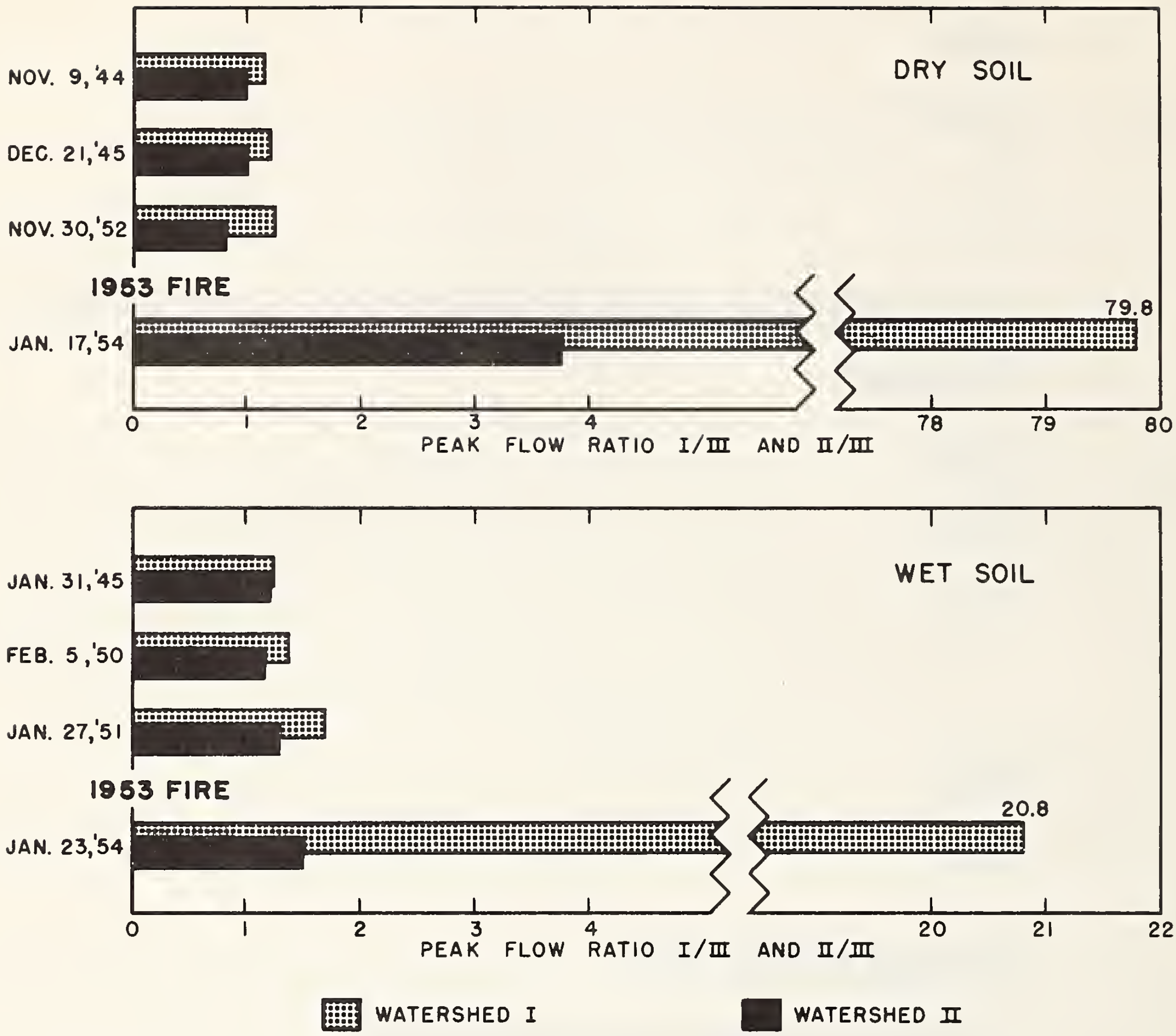


Figure 4.--Relative magnitudes of peak flows before and after the 1953 fire--peak flows per square mile from watersheds I and II relative to those from watershed III, unburned in 1953.

When compared as explained for the 1938 fire, the peak flows from watersheds I and II were found to be raised to the following levels by the 1953 fire:

	Dry soil conditions	Wet soil conditions
Watershed I, 32 percent burned	67.7 times normal	15.6 times normal
Watershed II, 3 percent burned	3.7 times normal	1.2 times normal

It is evident that the burning of even small portions of watersheds within the Experimental Forest exerts marked effects upon the peak flows. Effects of the same kind have been observed, and occasionally measured, in many parts of southern California. Had the 1953 fire burned over the whole of watershed I, it is doubtful that records such as these could have been obtained, for the peak flows following would undoubtedly have overwhelmed the streamgaging installation. Flows of these magnitudes have been experienced this year, with extremely damaging consequences, from nearby watersheds entirely burned over by recent fires.

Erosion after Fire

Erosion from the burned-over area of watershed II exceeded 8,850 cubic yards per square mile during the first storm after the 1938 fire. This estimate of erosion is based on measurements of debris trapped in catchment basins below three small watersheds situated within the burned area in the headwaters of watershed II. Two of the basins overflowed with debris during this storm; hence an accurate determination could not be made of the total amount of material washed from the slopes and channels above them. Watershed III was not equipped with a catchment basin; but according to notes made by field observers at the streamgaging station, the stream was charged with an abnormal amount of debris, indicating unusual erosion from the burned portion of the watershed. No erosion was observed in watershed I and other unburned areas of the Experimental Forest during this storm. This lack of debris movement in the unburned watersheds is evidence that the considerable amounts of erosion measured in watershed II and indicated in watershed III were a direct result of burning the vegetation cover.

Measurements could not be made of material eroded from watershed I after the fire of December 1953, for this watershed is not equipped with a catchment basin. Upon examination of the burned area after the storms of January 17-20 and January 23-25, 1954, it was estimated that on the average more than .6 of an inch of ash, soil, gravel, and decomposed rock was removed from the side slopes by sheet and rill erosion (fig. 6B). In addition to the slope erosion it was estimated that more than 3,000 cubic yards of material were removed from the burned area by bank cutting and scouring in the steep headwater channels of the watershed (fig. 7A). Judging by these estimates, more than 42,000 cubic yards of soil and other debris were washed from the 484 acres of burned area in the watershed. This quantity represents an erosion rate of 55,500 cubic yards per square mile of burned area.

The normal erosion rate for the San Dimas Canyon drainage above the San Dimas reservoir of the County Flood Control District, which includes Watershed I, has been computed from sedimentation measurements in the reservoir to be about 2,000 cubic yards per square mile per year. The erosion rate for the two storms following the fire in watershed I, then, is about 28 times the average annual rate for unburned watersheds in this area. No erosion was observed in any of the unburned watersheds of the Experimental Forest during these storms (fig. 11).

Erosion resulting from the fire in watershed I was not confined to the actual burned area. During the storms bank cutting and channel gouging were severe along the main stream for some 2 miles below the burned area (fig. 10). As the stream discharge dropped after the high flows, heavy deposition occurred throughout long reaches of the channel, filling some of the more gently sloping sections to the high-water mark. All the debris washed from this watershed this year, and much of the material recently deposited in its main channel, will move into the San Dimas reservoir, reducing storage capacity for water conservation and flood control.

FIRE-FLOOD SEQUENCES IN AN ADJACENT POPULATED AREA

Palmer Canyon is a watershed of about 700 acres, situated just south of Wolfskill Canyon and outside the Experimental Forest. It is easily accessible from the San Gabriel and Santa Ana Valleys and, like many other shady foothill canyons, contains many cabins built for weekend retreats or yearlong occupancy. This canyon contained about 65 cabins and 20 year-round residences. The Barrett fire breakout swept over most of the headwaters of the Palmer drainage, consuming the chaparral cover down to the ground. The fire-denuded slopes were subjected to at least 10 inches of rain in the January 1954 storms. Rain ran off the bare slopes, tearing them into a network of rills and gullies (fig. 12). Flood flows concentrated in the main channels and produced debris-laden crests which surged down through the cabin-lined area, destroying the canyon road, washing away two houses, and damaging at least half of the others (figs. 13 and 15). Automobiles were washed about and some smashed into useless scrap (fig. 14). Residents had received warning and had evacuated the area. No lives were lost, but the losses in developments and property were great.

Thus we have the sequence: fire destroys the protective cover of a watershed; heavy rains on the newly denuded slopes result in destructive floods.

Figure 5.--The upper part of watershed I, Wolfskill Canyon of the San Dimas Experimental Forest, from the south ridge. Elevations range from 3,100 feet in foregound, to 4,800 feet on background ridge. A: The watershed in 1945, unburned for more than 50 years. B: The watershed in 1954, after the far slopes had been burned by the Barrett fire break-out of December 1953.

Figure 6.--Slopes above an elevation of 4,100 feet in watershed I. A: Old chaparral and bigcone spruce in 1945. B: The same slopes early in 1954 denuded by the 1953 fire and rilled by 13 inches of rain in January. Soil washing has nearly obliterated the trail.

Figure 7.--Channels in watershed I after the storms of January 1954.
A: At 4,100 feet elevation small drainages were cut to bedrock.
B: This normally V-shaped, boulder-strewn channel below the burned area was filled 2 to 6 feet deep. The cloth strip shows the height of flood flow in one of the January storms.

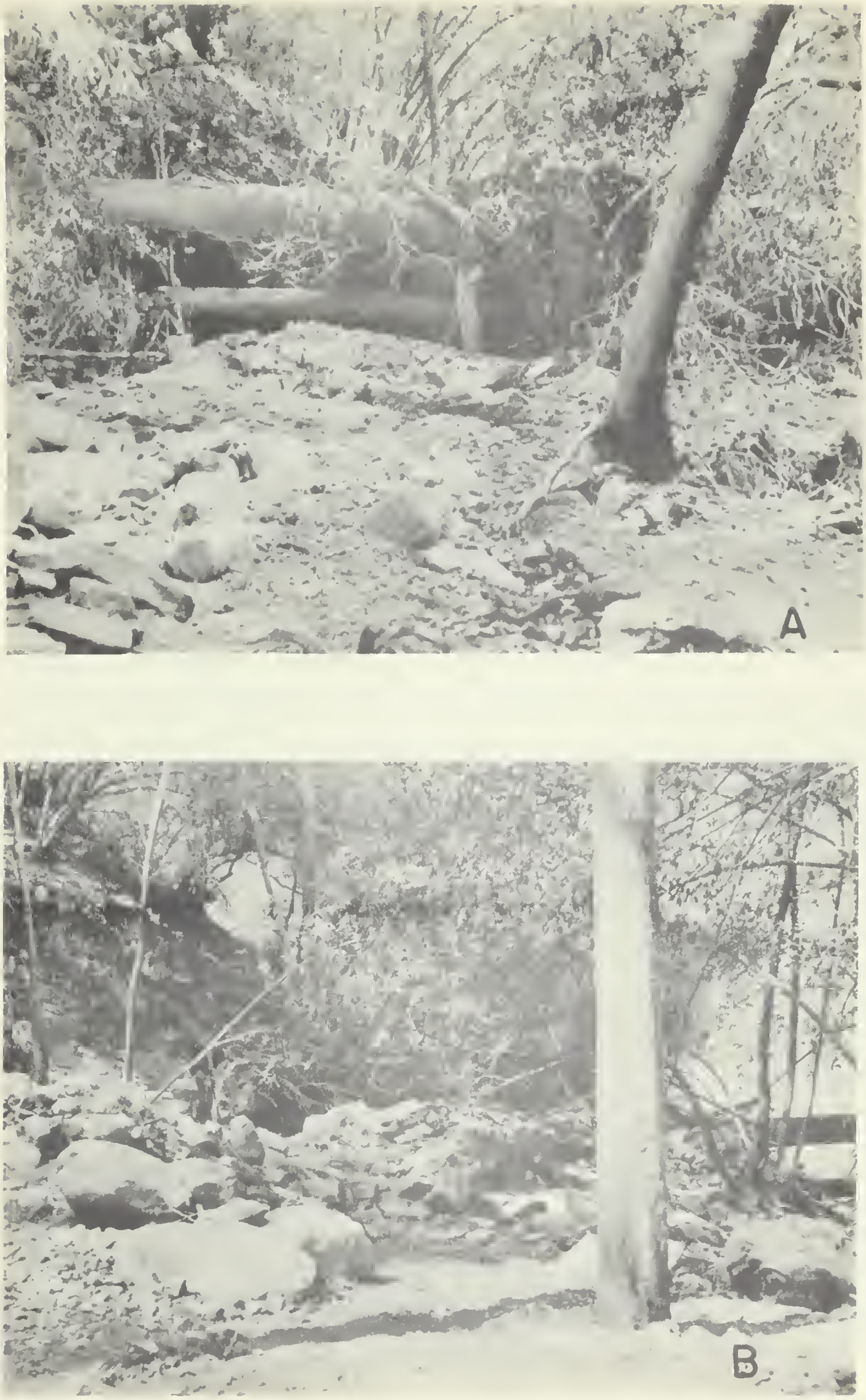


Figure 8.--The lower main channel of watershed I after the January 1954 storms. A: Looking upstream at alder logs more than 30 feet long that had washed downstream, lodged against trees, and formed a dam. B: Looking downstream at the same dam. Water had ponded against the obstruction until the debris gave way at the right.

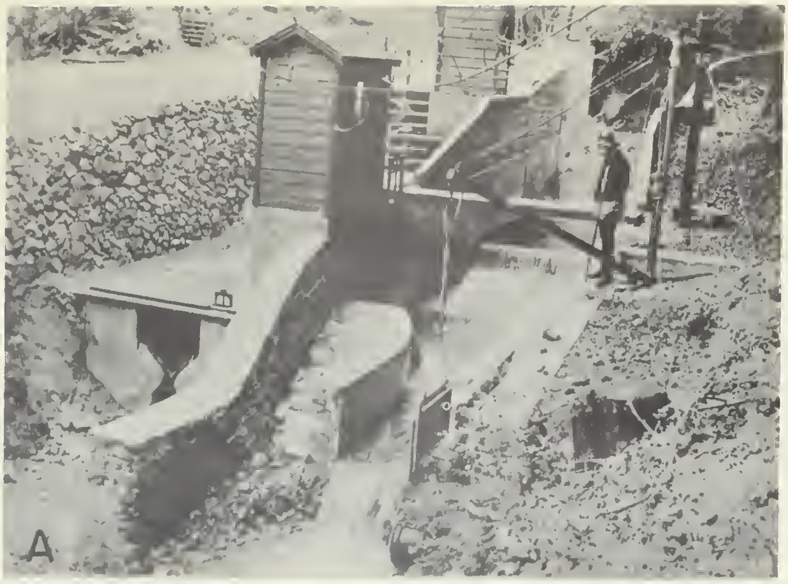


Figure 9.--The streamgaging station at the mouth of watershed I. A: In 1941 the approach to the 10-foot flume, background, was unobstructed. During the storm of January 17-20, 1954 a boulder 4 feet in diameter was jammed into the entrance of the 3-foot flume in the foreground. B: On January 26, 1954 the upstream approach to the 10-foot flume was strewn with boulders and other debris deposited during storms of the preceding 7 days. The cloth strip shows the height of one of the flow peaks in the 10-foot flume.

Figure 10.--Several hundred yards below the watershed I streamgaging station debris-laden flows of the January 1954 storms clogged this bridge. The diverted flows then washed out part of the bridge and cut through the road.

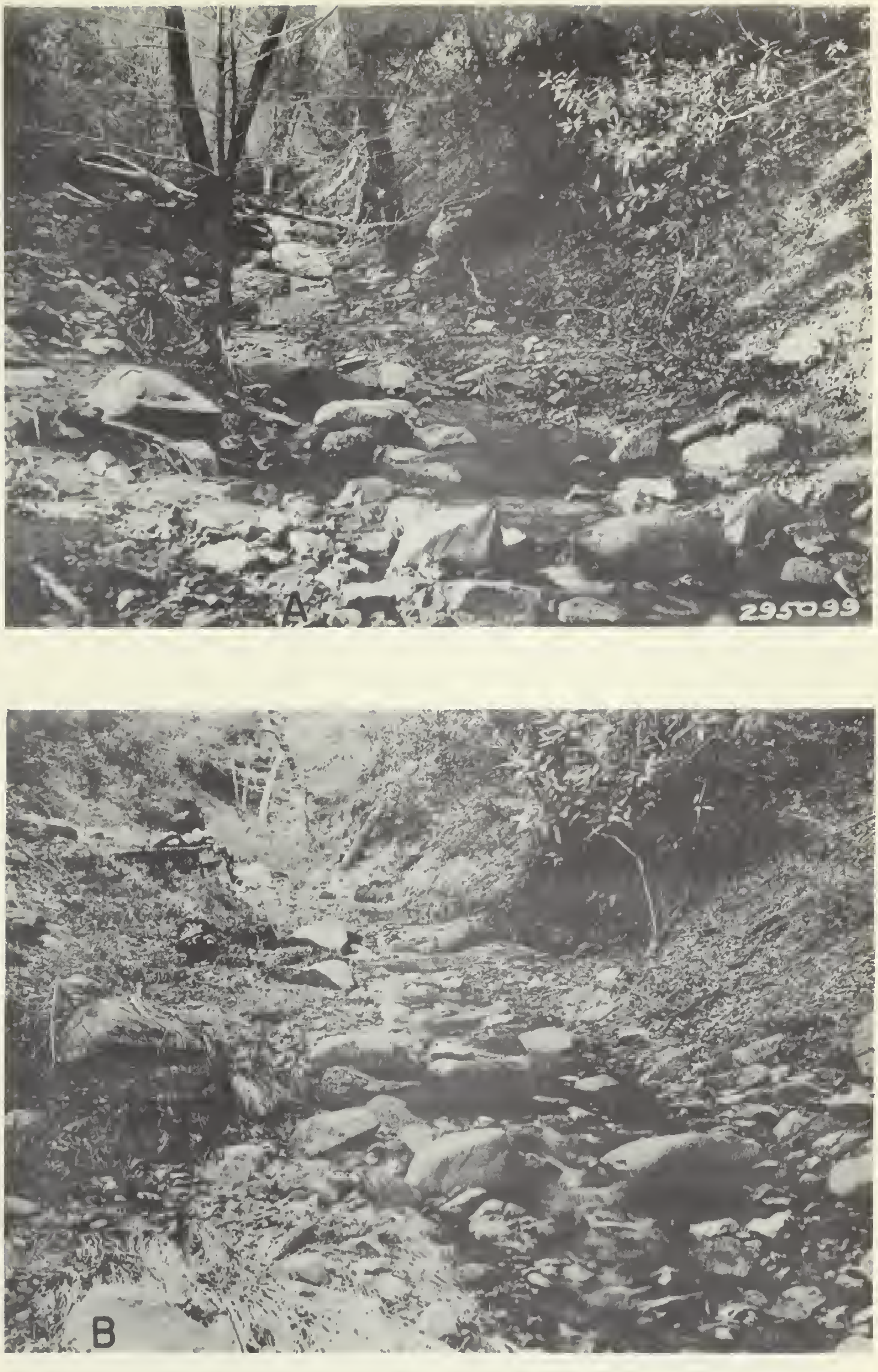


Figure 11.--The stream-bottom of watershed V, less than half a mile from the Watershed I gaging station. This watershed is almost twice the size of watershed I, and has been unburned since 1919. A: The channel in January 1934. B: The channel in March 1954, showing that little change has taken place in 20 years. Compare this with figures 7B and 9B.

Figure 12.--The upper slopes of Palmer Canyon, just south of and outside the Experimental Forest. These slopes were burned over by the Barrett Fire break-out in December 1953, and were rilled by at least 10 inches of rain in January 1954.

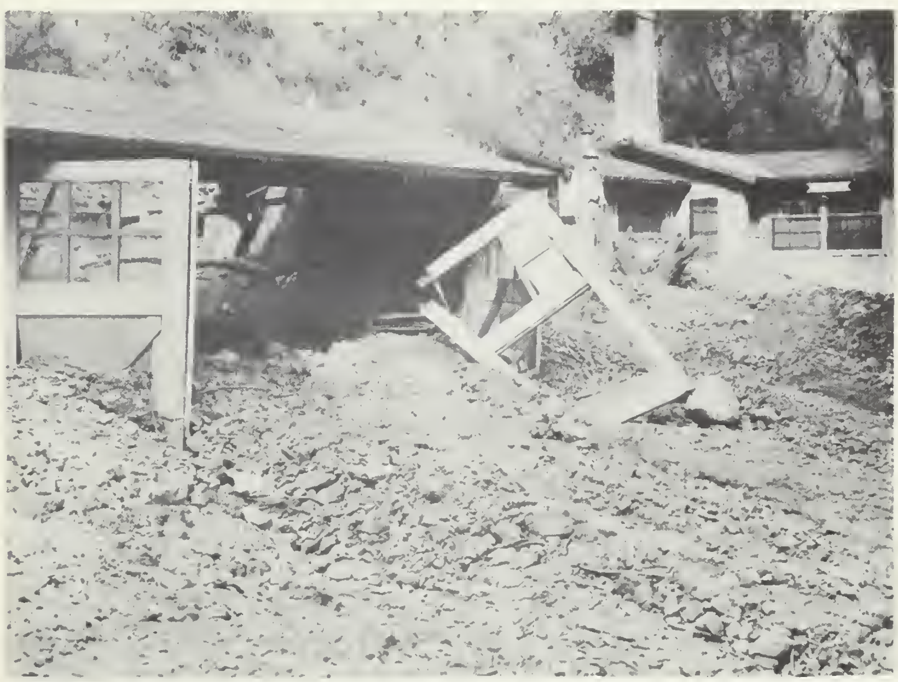


Figure 13.--The lower part of Palmer Canyon in March 1954. Mud, gravel, and rocks washed from the burned slopes and channels in January caused this damage below a tributary whose flow had previously been carried by a culvert 24 inches in diameter.

Figure 14.--Farther down in Palmer Canyon debris-laden flows sweeping through the residential section wrapped this automobile around a tree.

Figure 15.--Near the mouth of Palmer Canyon flood flows gained sufficient volume and speed to demolish this residence, washing away nearly everything but the living-room fireplace.